High-resolution spectroscopy of gases at elevated temperatures with applications to combustion

Fateev, Alexander; Clausen, Sønnik

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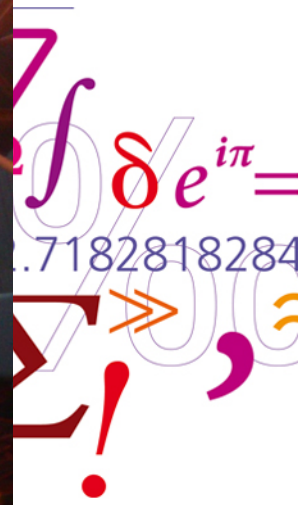
High-resolution spectroscopy of gases at elevated temperatures for industrial applications

Alexander Fateev and Sønnik Clausen

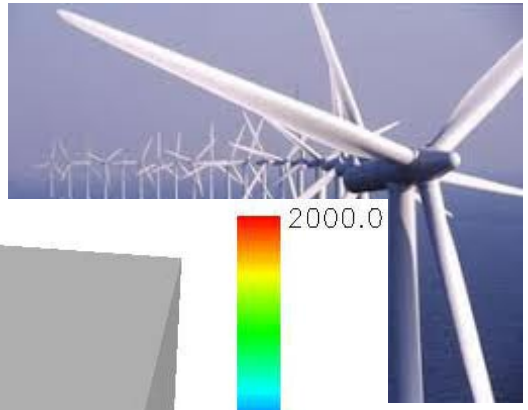
Optical Diagnostics Group,
DTU Chemical Engineering, Frederiksborgvej 399, Roskilde, DK-4000, Denmark

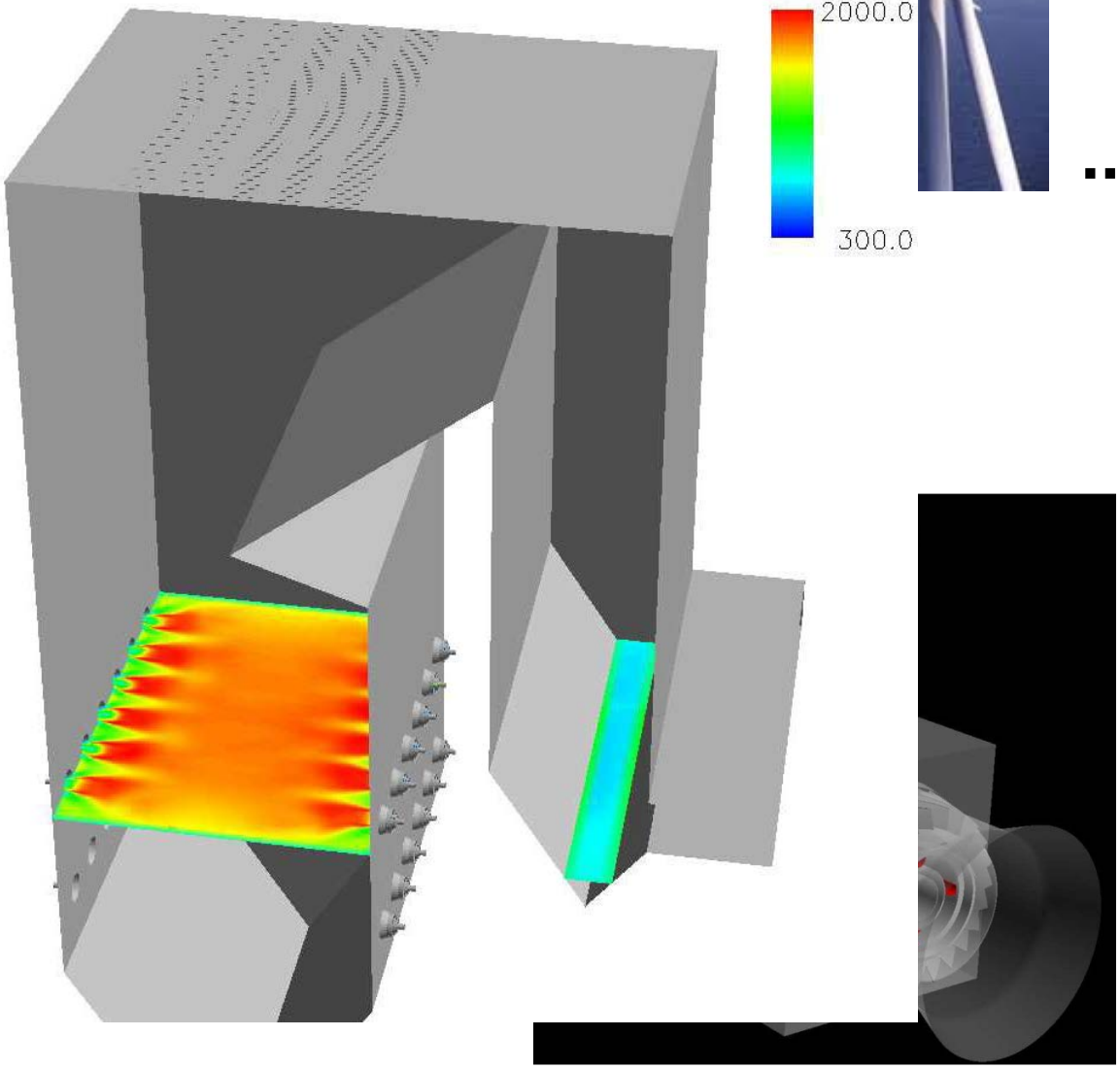


Outline

- Large scale measurements: why?
- Basic research: how it's made
- High resolution spectroscopy in flow gas cells: H2O and CO2
- SO3 project: the story
- Conclusions

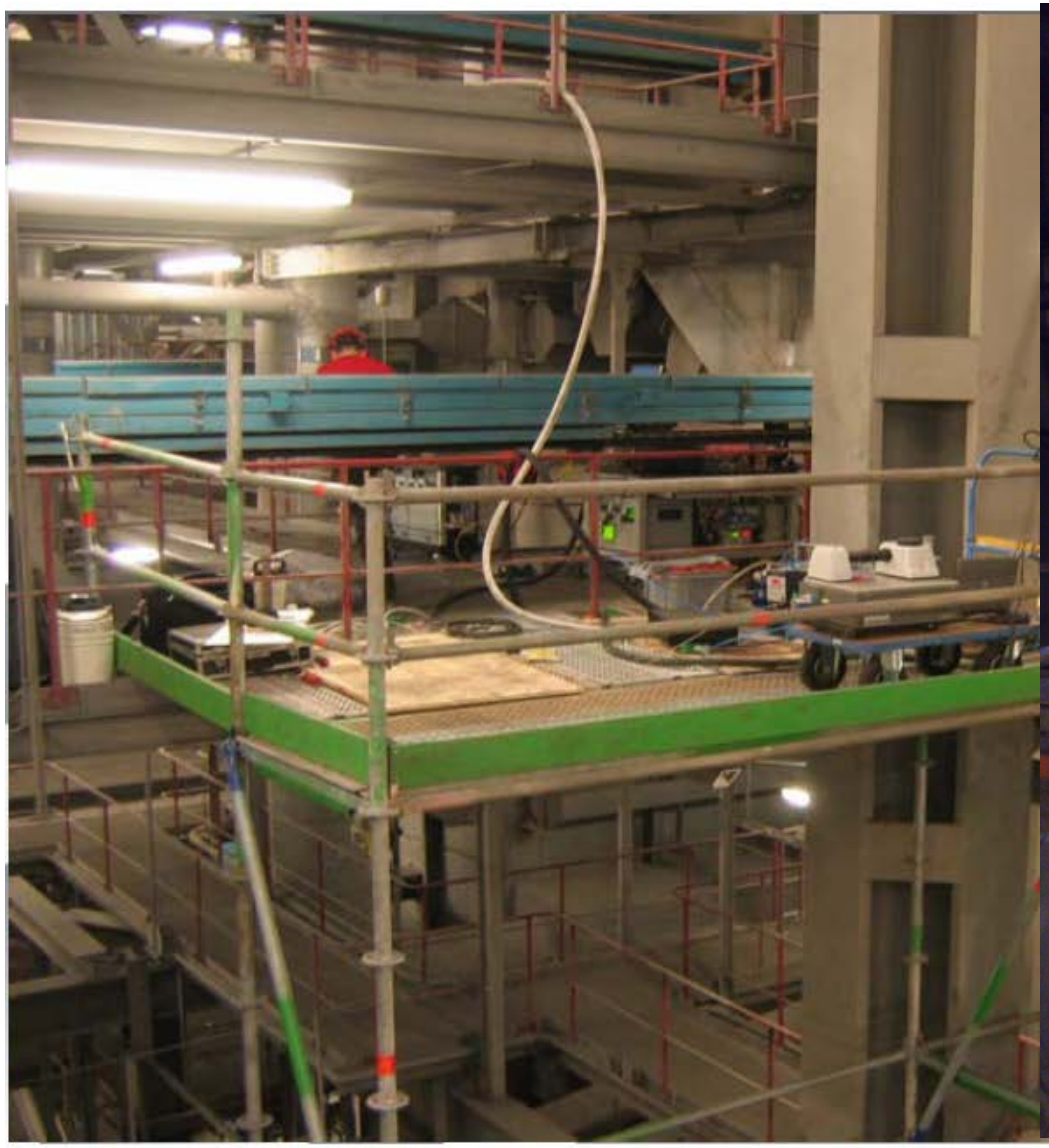
Green Energy…





… well

Large scale measurements



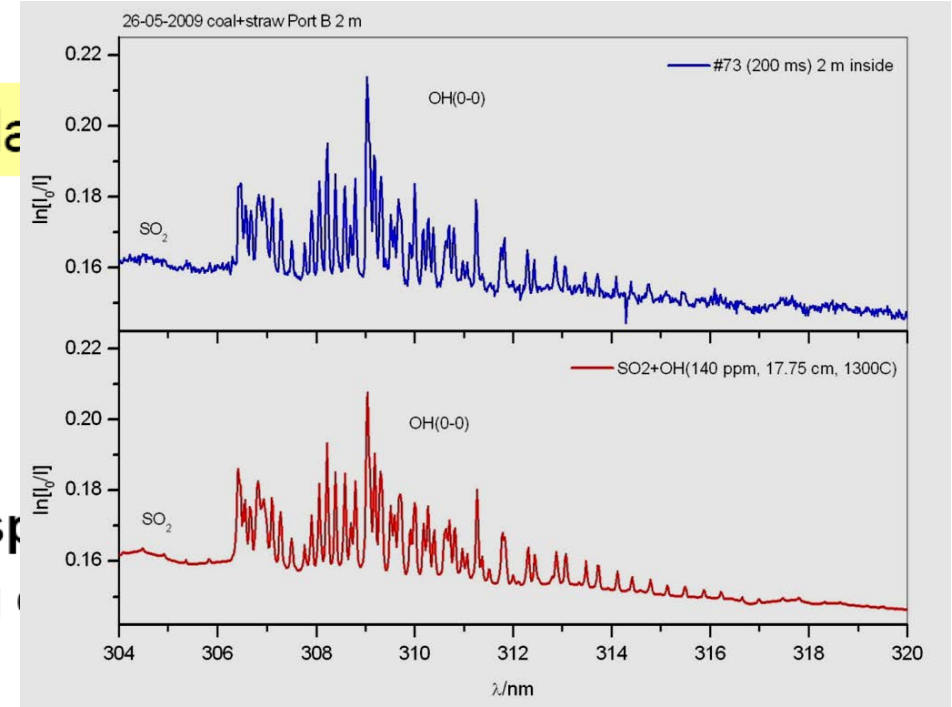
Large scale measurements

Fiber optical probes

- FTIR spectroscopy (emission): >5 m, 45 mm probe

  H_2O, CO_2, CO, C_xH_y, HCl, etc. + T_{gas} + T_{par} + ε
- UV spectroscopy (transmission): 9 m, 60 mm probe

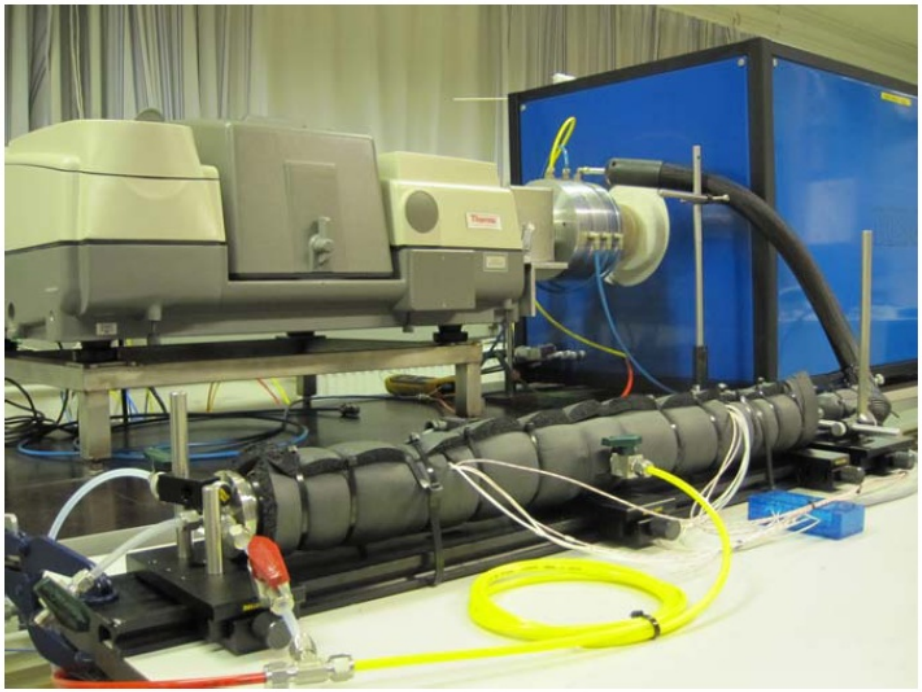
  SO_2, NO, O_2, etc.

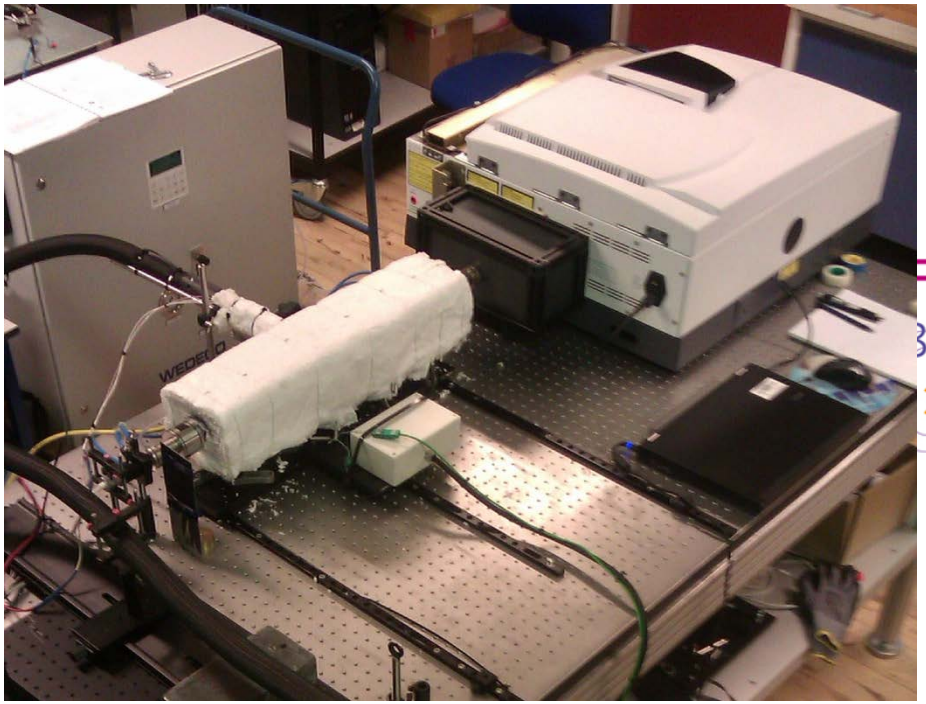


Basic research

- focus on optical properties (TRS, ABS) of gases at temperatures up to 1600C;
- validation/building databases (e.g. HITRAN/HITEMP/CDSD…);

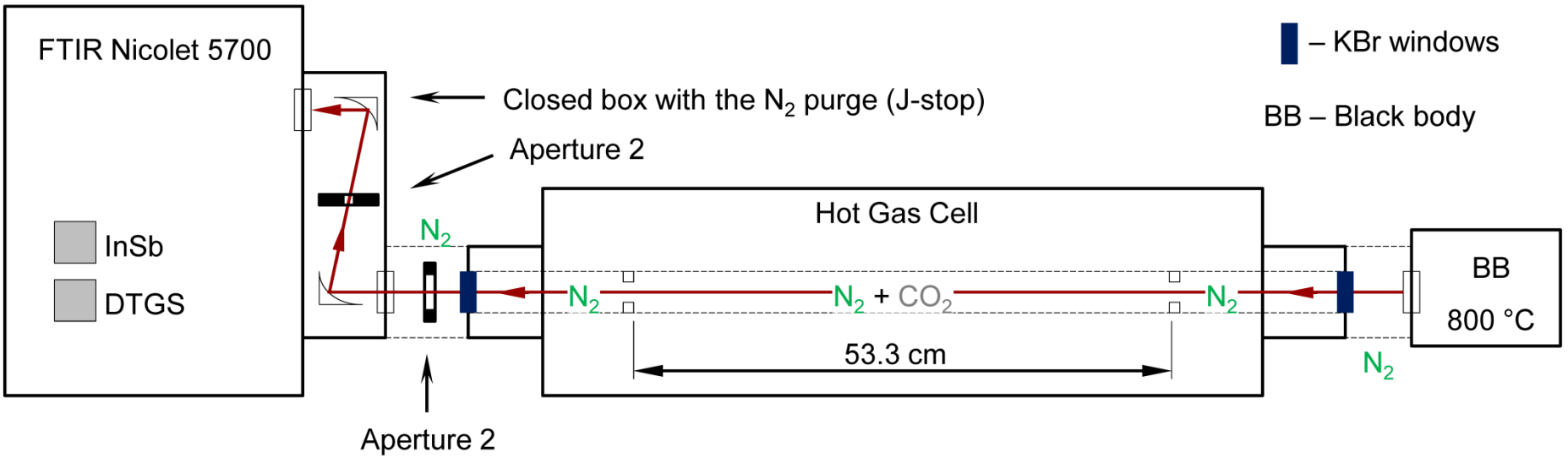
- high-resolution spectroscopy (0.125 cm-1/0.016 nm) of “major” and “minor” (or trace) gases : CO2, H2O, SO2, NH3, SO3, H2S, OCS, HCL, CH3Cl, PAH’s etc;
- various hot gas cells with highly-uniform temperature profiles (±0.5C).





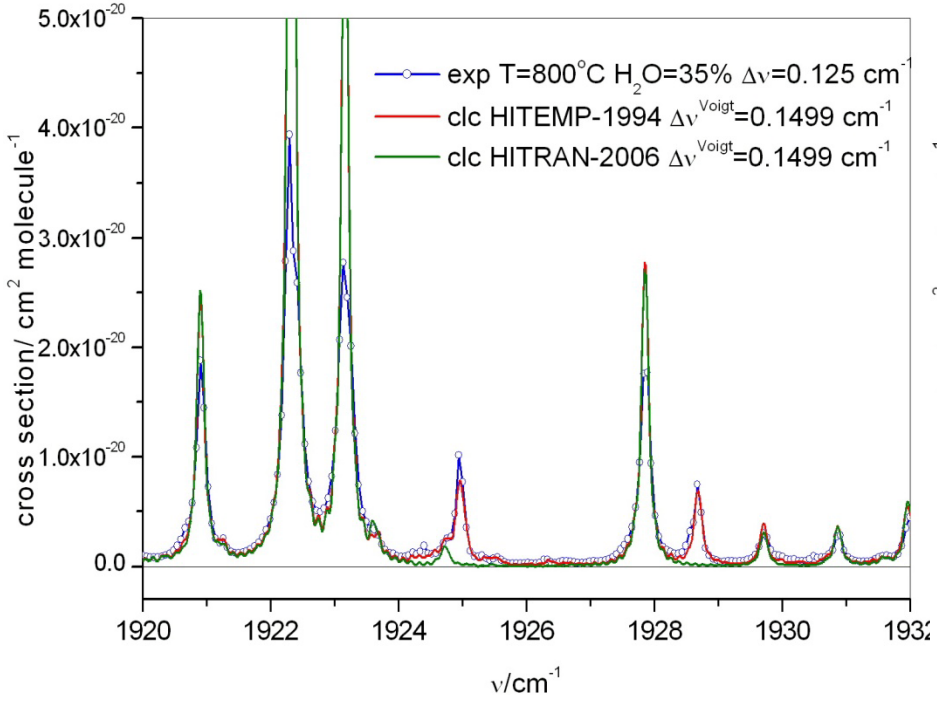
Experimental set up

Includes:
- a gas cell;
- a high-resolution FTIR spectrometer (Nicolet or Agilent);
- a light source (BB).

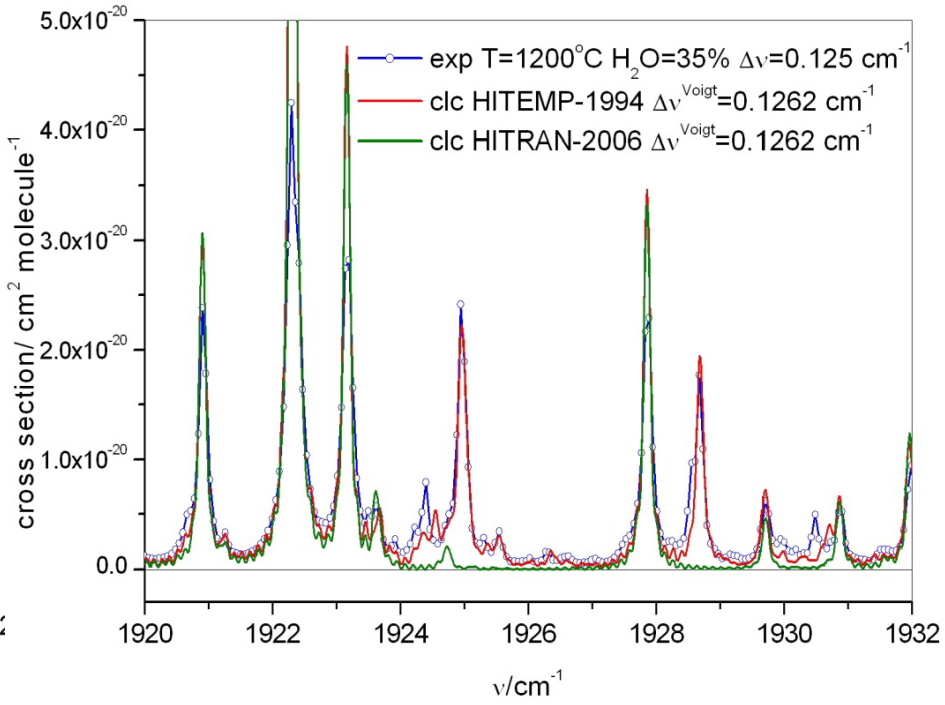


Examples: H2O absorption cross sections

T=800C



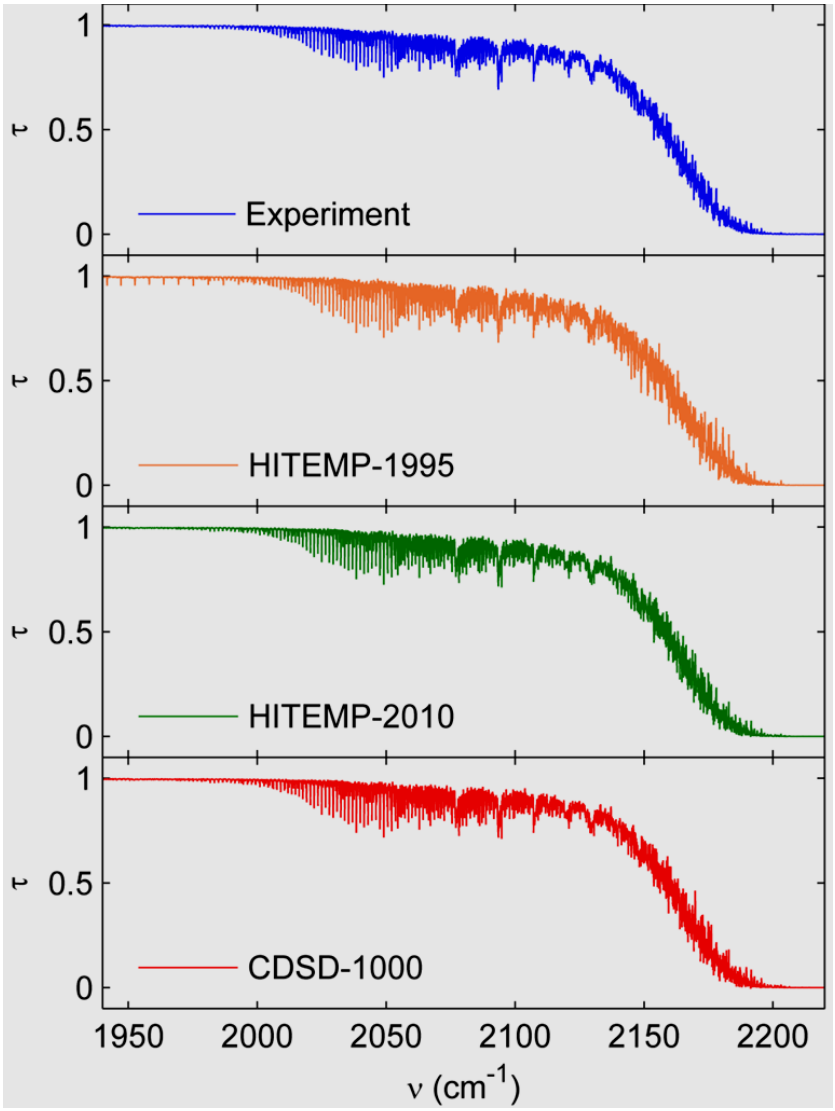
T=1200C

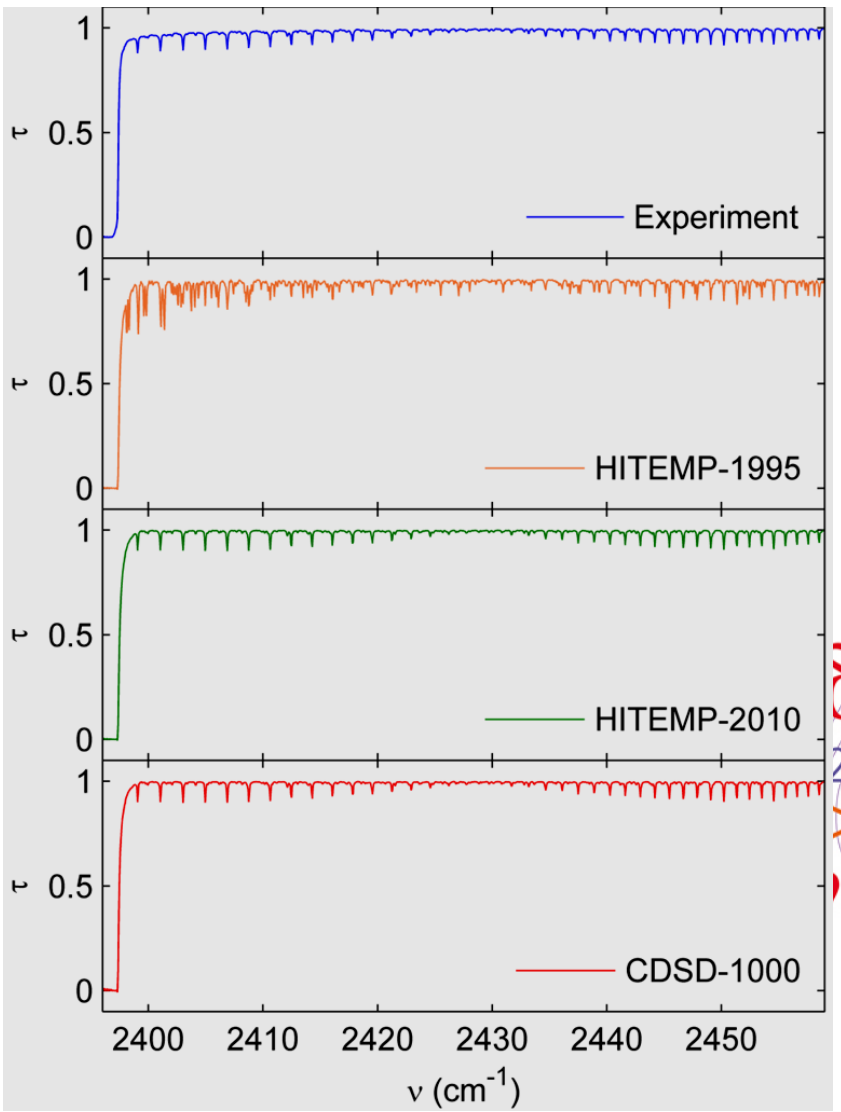


- Good agreement between EXP and CLC(HITEMP-1994);

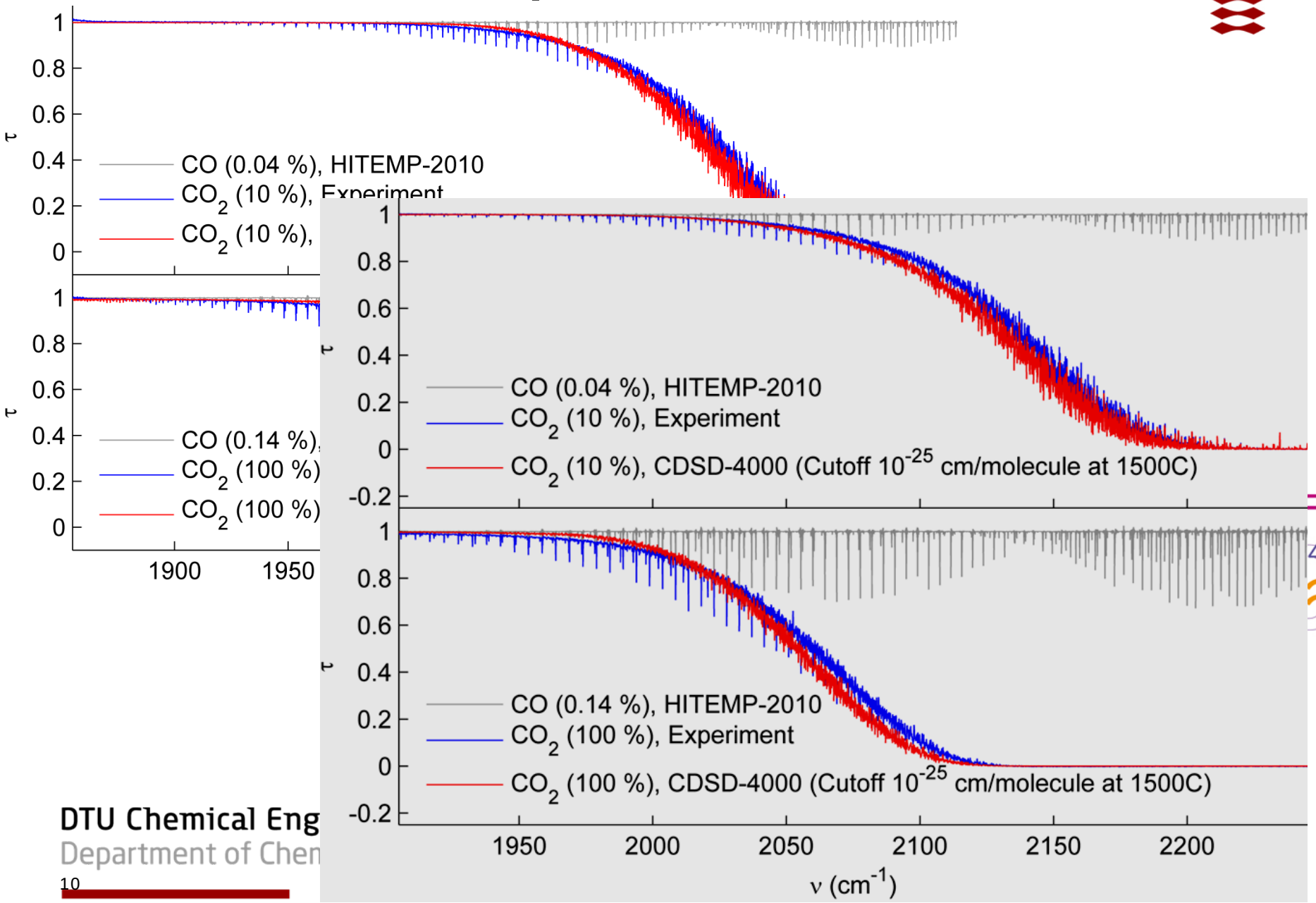
- Different FWHM values of the H2O single lines for H2O(35%) in N2 and H2O(35%) in CO2 (oxyfuel combustion).

CO2 transmission spectra: 727C

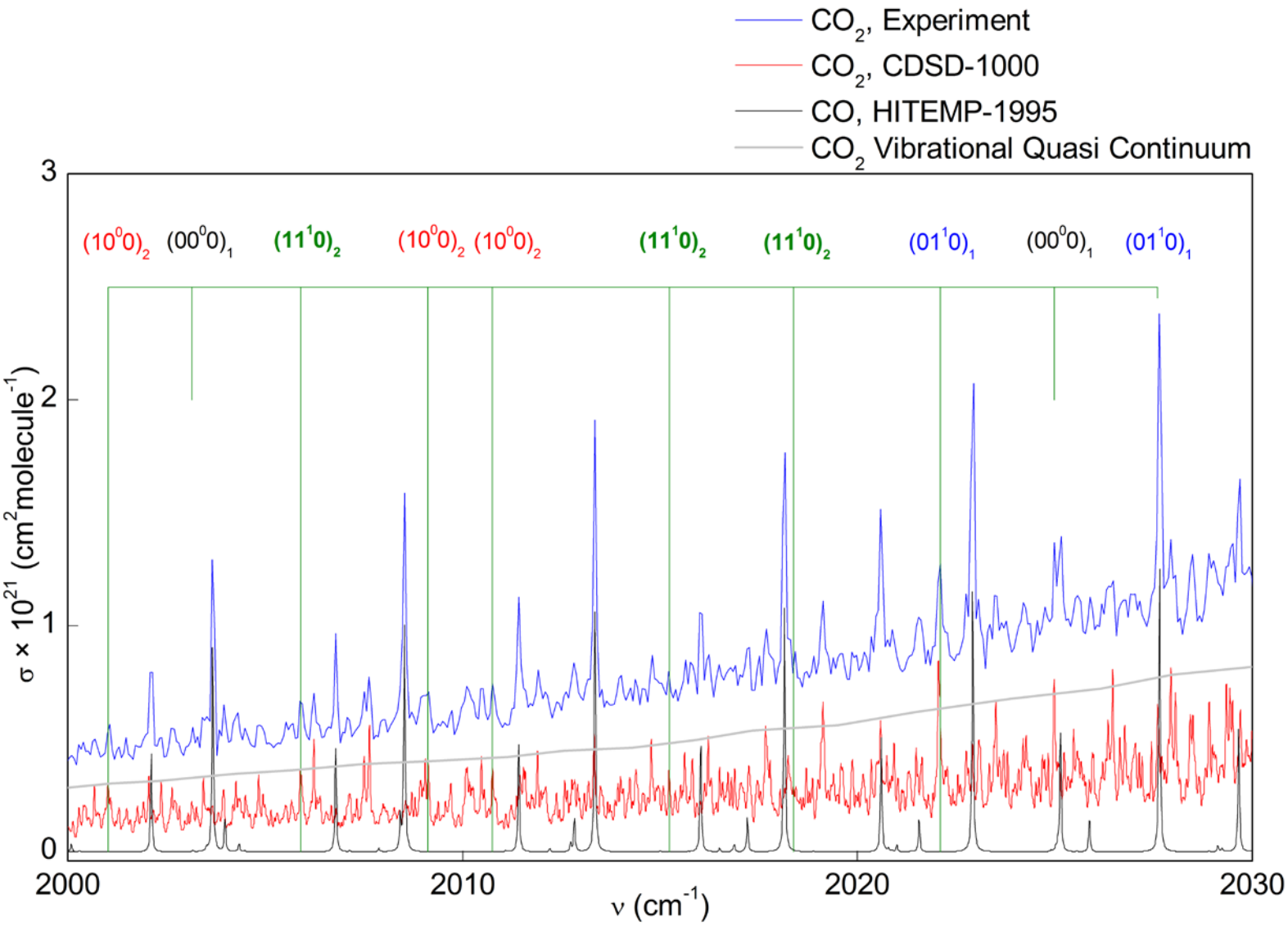




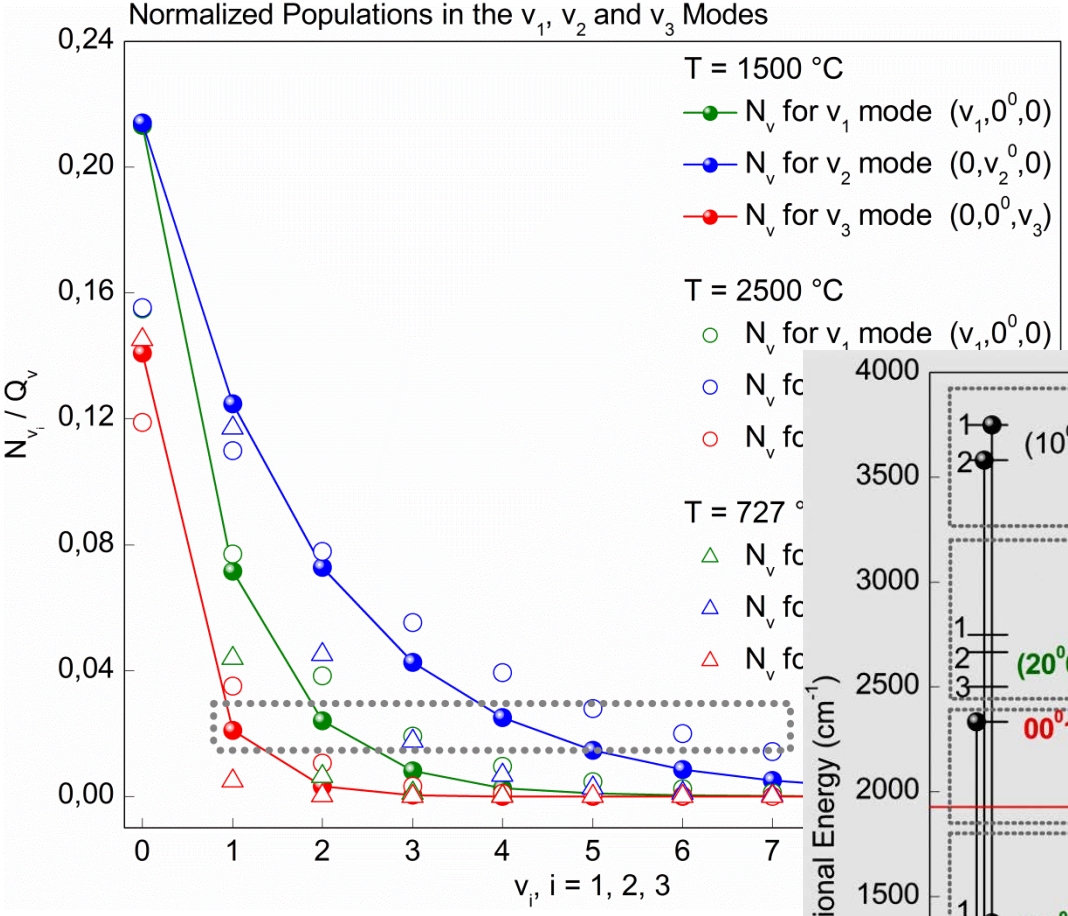
CO2 transmission spectra: 1500C

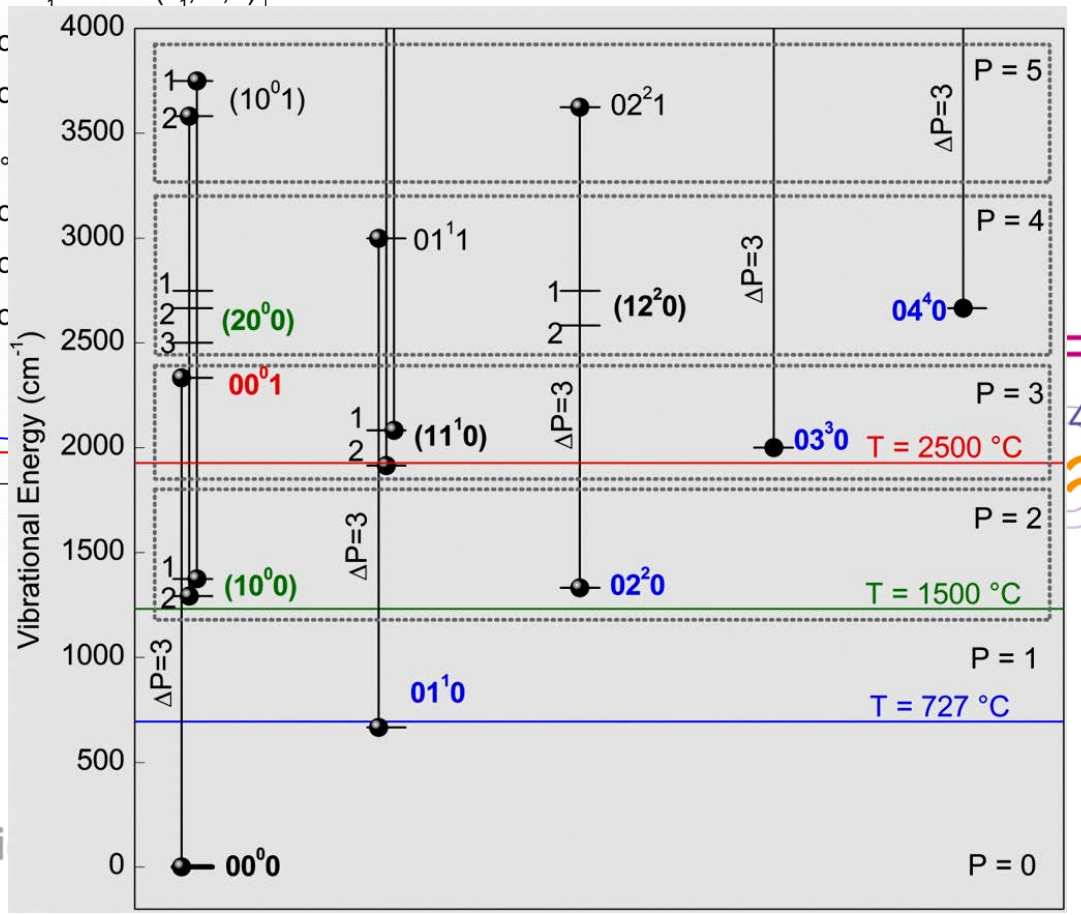


CO2 quasicontinuum at 1500C



CO2 quasicontinuum at 1500C





SO3 project: industry and university

Facts:

- Coal air combustion: SO2(300ppm) and SO3(5ppm) (blue smog);
- Large power plants: SCR units (NOx reduction) with NH3 injection;
- Global warming: operation at lower loads;
- Lower loads: lower gas temperatures at SCR units;
- By law: not allowed to turn off NH3 injection system.

Problems:

- Non optimal NH3 consumption;
- At lower T: H2SO4 formation which causes ammonia sulfate and ammonia bisulfate formation;

Consequences:

corrosion in ducts and plugging/damage of SCR elements.

Goal:

to develop an optical method for SO3 ***in situ*** measurements.

SO3 project: industry and university

Challenges of the project:

- temperature range 200-500C;
- SO3 high-resolution spectra (SO3 generation);
- SO2, NH3, H2SO4 and H2O high-resolution spectra database;

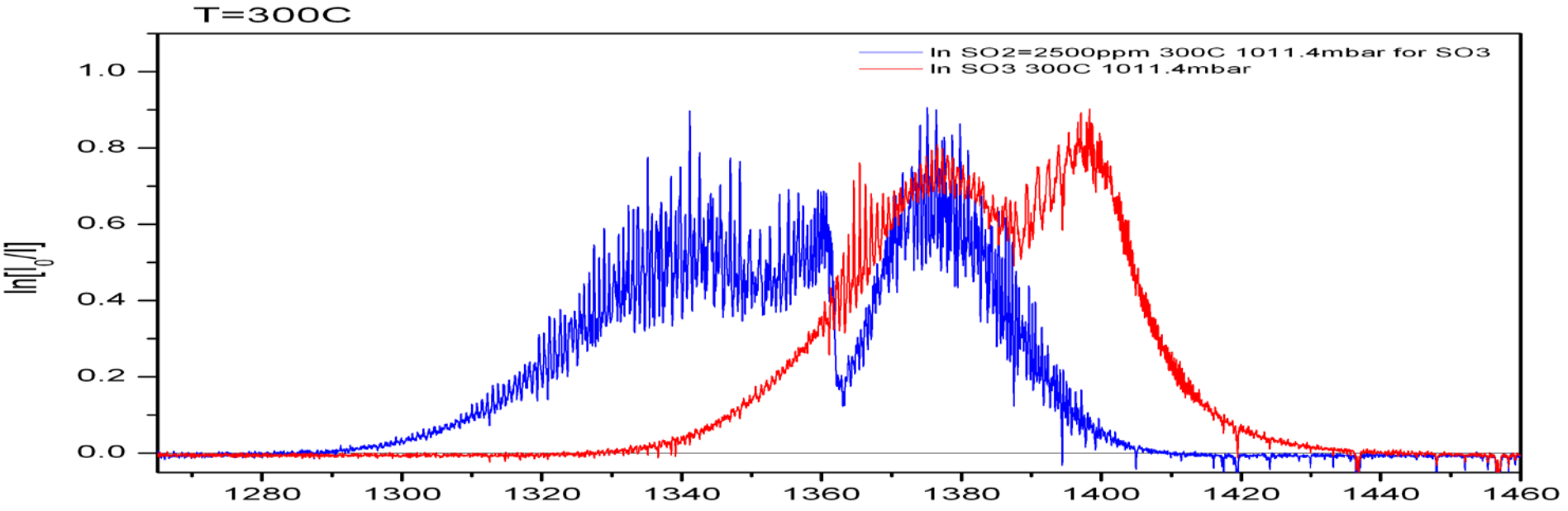
- water cooled optical probe development;
- powerful IR light source development;
- high sensitivity FTIR with linearized MCT or InSb detector;
- use of modern mathematical tools (e.g. SVD, NNLS).

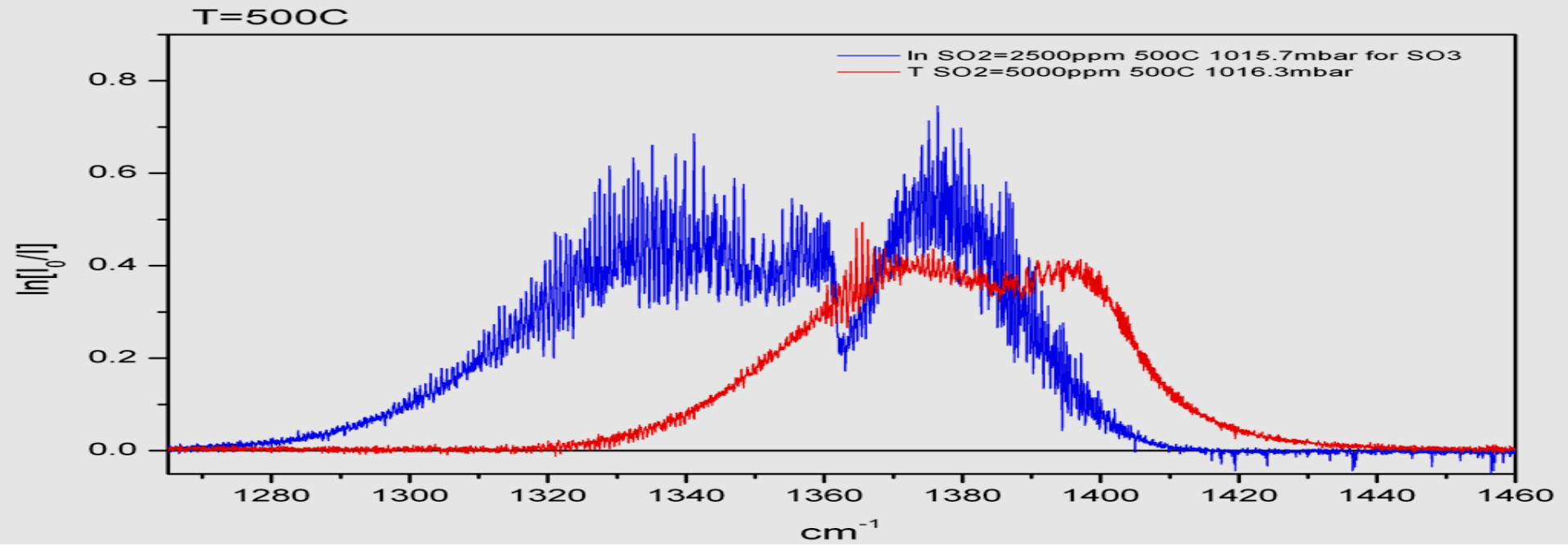
Two phases of the project:

- measurements in the lab and SO2/SO3 line list generation (UCL, UK)

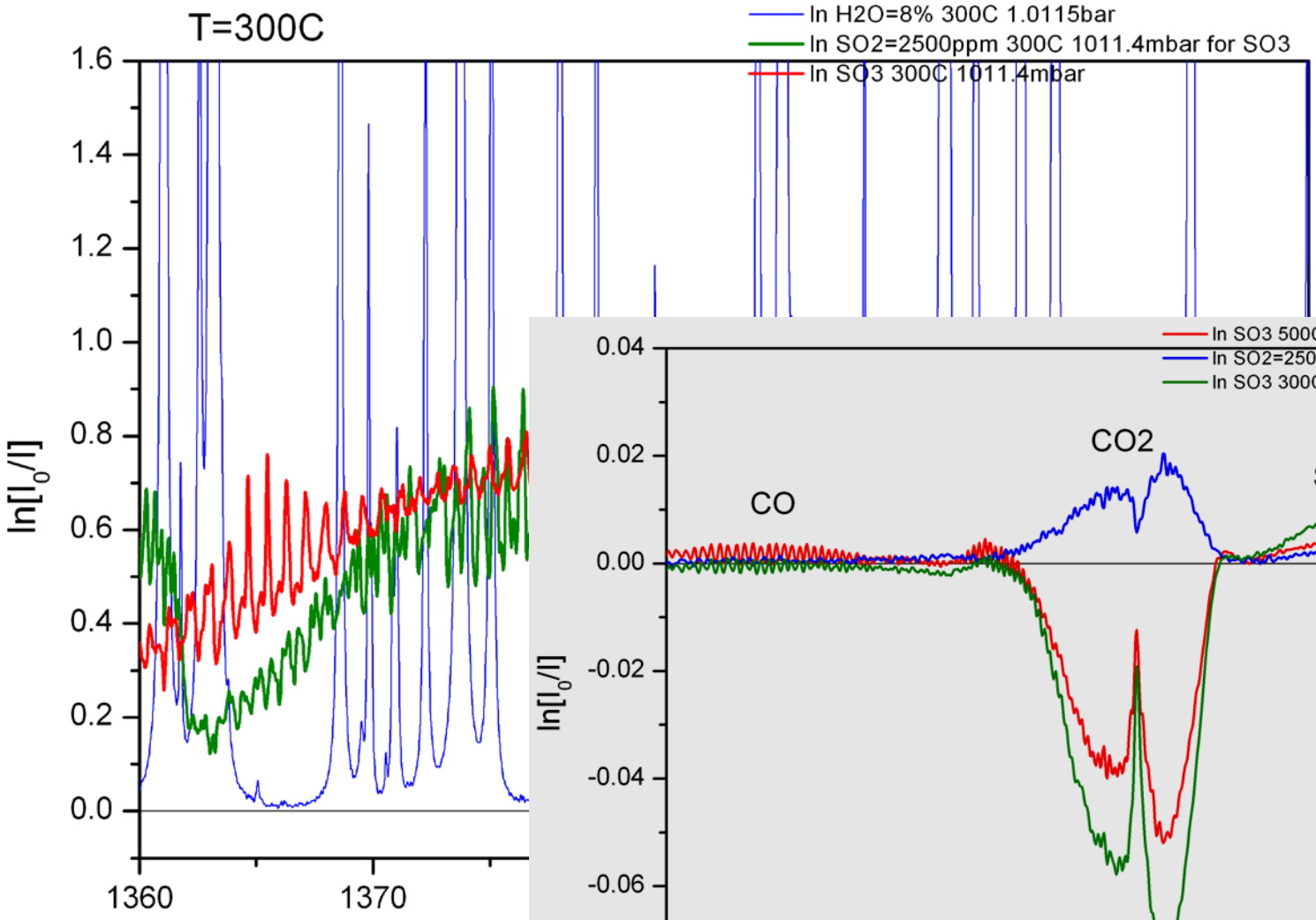
- measurements on an industrial scale (power plant, Dong Energy, DK)

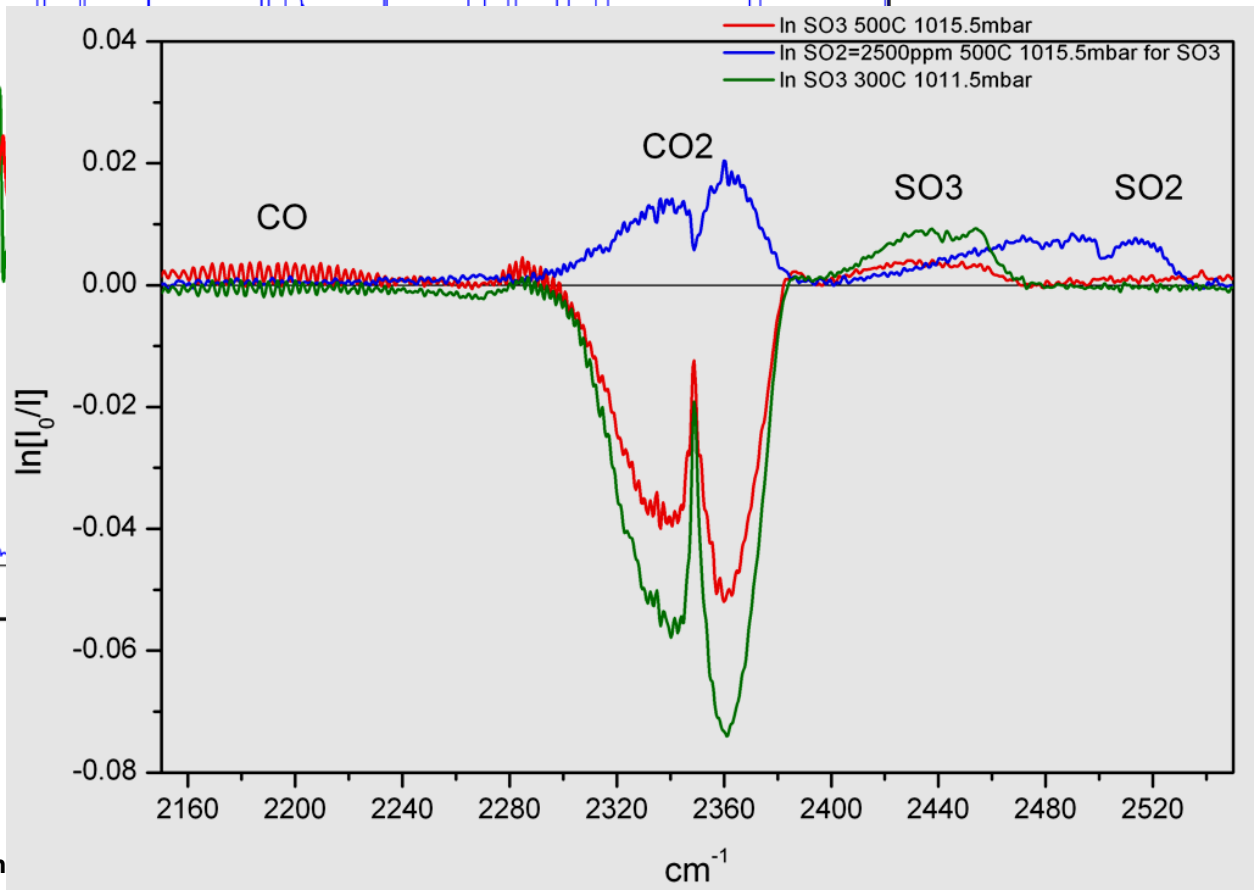
SO3 project: high-resolution (0.115 cm-1) measurements





SO3 project: interferences





Conclusions

High quality optical measurements with various gases (incl. highly corrosive gases) are possible;

A new gas cell is under development (<200 bar, 2000C)

Measurements can be used for: databases development and validation, studies of chemical reactions, energy exchange, validation of line shape models.

SO3 project is under development: lab work + PhD student employed by UCL;

Acknowledgements

- Energinet.dk: project No. 2010-1-10442
- Dong Energy (Mr. Jan N. Hvidberg)
- UCL (Prof. Jonathan Tennyson)